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**BEFORE THE BOARD OF PATENT APPEALS
AND INTERFERENCES**

Application Number: 10/823,364
Filing Date: April 12, 2004
Appellant(s): SHANNON ET AL.

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Alan Taboada
For Appellant

EXAMINER'S ANSWER

This is in response to the appeal brief filed on 3/10/2008 appealing from the Office action mailed 10/11/2007. Note: Previous Examiner’s Answer mailed on 4/18/2008 has been vacated in view of the remand from the Board of Patent Appeals and Interferences mailed on December 8th 2008. This examiner’s answer with includes the correct grounds of rejection for claims 34, 35, 37, 38, 39 and 43-46.

(1) Real Party in Interest

A statement identifying by name the real party in interest is contained in the brief.

(2) Related Appeals and Interferences

The examiner is not aware of any related appeals, interferences, or judicial proceedings which will directly affect or be directly affected by or have a bearing on the Board's decision in the pending appeal.

(3) Status of Claims

The statement of the status of claims contained in the brief is correct.

(4) Status of Amendments After Final

The appellant's statement of the status of amendments after final rejection contained in the brief is correct.

(5) Summary of Claimed Subject Matter

The summary of claimed subject matter contained in the brief is correct.

(6) Grounds of Rejection to be Reviewed on Appeal

The appellant's statement of the grounds of rejection to be reviewed on appeal is correct.

(7) Claims Appendix

The copy of the appealed claims contained in the Appendix to the brief is correct.

(8) Evidence Relied Upon

2003/0127319	Demaray et.al.	7-2003
2003/0148611	Dhindsa et.al.	8-2003

Georgieva, V *"Numerical study of Ar/CF_4/N_2 discharges in single- and dual-frequency capacitively coupled plasma reactors",* Journal of Applied Physics, vol.94, No.6, (Sept. 15, 2003) pp.3748-3756

Lieberman M.A. et.al. *"Standing wave and skin effects in large-area, high-frequency capacitive discharges",* Plasma Sources Science and Technology, vol.11, (June 14, 2002), pp. 283-293

(9) Grounds of Rejection

The following ground(s) of rejection are applicable to the appealed claims:

(a) Claims 1-3 and 10 are rejected under 35 U.S.C. 103(a) as being unpatentable over Demaray et al. (US 2003/0127319).

As to claim 1, the reference of Demaray describes a method of controlling the deposition and etching characteristics of plasma on a semiconductor substrate (16) (page 3, paragraph 0025, page paragraph 0048/0049) in a processing chamber using a dual frequency RF source comprising:

Supplying a first (14) and second (15) RF signals to an electrode, wherein an interaction between the first and second signals is used to control at least the plasma density, ion bombardment and electron acceleration of plasma formed in the processing chamber (page 5, paragraph 0043).

It is noted that Demaray's method is suitable for optical devices, however, Demaray cites "target (12) is composed of wide band-gap semiconductor materials" (page 2, paragraph 0024) and a semiconductor substrate (16) (page 3,

paragraph 0025), in addition, one of ordinary skill in the art would know that PVD processes are conventionally used in semiconductor manufacturing.

Therefore, it would have been obvious to one of ordinary skill in the art at the time the invention was made to process semiconductor substrates for opto-electronic applications using the method of Demaray because Demaray discloses typical substrates are semiconductor wafers. One of ordinary skill in the art would be motivated to form opto-electronic semiconductors in order fabricate opto-electronic transducers in combination with integrated optical devices with good control of refractive index.

As to claim 2, Demaray discloses when power is applied a sheath is formed, the sheath serves to accelerate the ions (page 5, paragraph 0047), and dual frequency affects (or modulate) the ions and electrons acceleration (page 5, paragraph 0043), which reads on applicant's instant claim where the dual frequency causes a sheath modulation.

As to claim 3, Demaray discloses "The high frequency accelerates electrons in the plasma but is not as efficient at accelerating the much slower heavy ions in the plasma. Adding the low frequency RF power causes ions in the plasma to bombard the film being deposited on the substrate" (page 7, paragraph 0043). One of ordinary skill in the art would know that ion bombardment strong enough to sputter must be generated by a strong self-biasing sheath in the plasma.

As to claim 10, Demaray uses dual frequency for the target to improve film characteristics as well as film uniformity, which is an attribute of power distribution uniformity (page 2, paragraph 0023).

(b) Claims 40-42 are rejected under 35 U.S.C. 103(a) as being unpatentable over Demaray et al. (US 2003/0127319) as applied to claim 1 above, in further view of Dhindsa (US 2003/0148611).

Demaray fails to disclose the disposition of a first electrode below the substrate support surface. However, Dhindsa discloses the electrode (202) beneath a substrate (204) support surface in the etch chamber (200) (paragraphs 0023 and 0024), wherein the electrode is a cathode (208) (paragraph 0024), etching a substrate disposed on the substrate support (paragraph 0024), wherein the electrode is disposed beneath a substrate support in the etch chamber (fig.2) (paragraph 0024). Therefore, it would have been obvious to one of ordinary skill in the art at the time the invention was made to select the position of first electrode below the substrate surface in the etch chamber because Dhindsa illustrates that positioning of the substrate would improve process uniformity across the entire wafer surface (paragraph 0026).

(c) Claims 4-9, 11 and 12 are rejected under 35 U.S.C. 103(a) as being unpatentable over Demaray et al. (US 2003/0127319) as applied to claims 1-3, 10 above, and further in view of Georgieva et al. (Journal of Applied Physics, Vol. 94, No. 6, Sept. 15 2003, pages (3748-3756).

It is noted that Demaray is silent about details of the ion energy distribution function (IEDF).

As to claim 4, the reference of Georgieva discloses, depending on the gas used, the IEDF varies from a broad distribution (figure 8) to a peaked well-defined distribution depending on the specific ions, pressure, power level and frequency. Applicant has not defined any scale for the energy spread, type of ions, power levels or frequency.

Therefore, it would appear that with proper choice of the above parameters, one of ordinary skill in the art would be able to obtain an IEDF of any desired shape as taught by Georgieva including a broad ion energy distribution for the first frequency and a peaked, well defined energy distribution for the second frequency as illustrated by Georgieva in figure 8 and in the Ion Energy Distribution section on page 3754.

As to claim 5, Georgieva teaches a detailed model on how ions respond the excitation frequency (cycle time, period) in the ion sheath. Applicant does not define any plasma parameter used for claim 5. Therefore, it would appear that one of ordinary skill in the art would be able to use the teachings of Georgieva in order to obtain a plasma wherein a first RF signal has a cycle time that is larger

than the transit time of an ion in the sheath, and wherein the second RF signal has a period that is equal to or greater than the transit time of an ion in the sheath since a processing plasma usually includes a multitude of ions (as illustrated by Georgieva) a combination of any two frequency is likely to yield one type of ions having a small mass and a transit time in the sheath that is smaller than a first frequency cycle time, and yield other ions, heavier, with a transit time nearly equal to the second frequency period. Applicant has not shown unexpected results associated with the ions transit time in the sheath as described in the instant claim.

As to claim 6, a peak-to-peak voltage is usually defined in the case of one frequency as being the voltage between the highest value to the lowest within on cycle, It would appear that a “peak-to-peak” sheath voltage needs to be defined in the case where two frequencies are superposed. The reference of Demaray teaches ” A theoretical model of the mechanism by which substrate bias operates, has been put forward by Ting et al. (J. Vac. Sci. Technol. 15, 1105 (1978)). When power is applied to the substrate, a so-called plasma sheath is formed about the substrate and ions are coupled from the plasma. The sheath serves to accelerate ions from the plasma” (page 5, paragraph 0047). The dual frequency powers will therefore control the sheath or self-biased DC potential.

As to claims 7 and 8, Demaray clearly cites the effect of each frequency on the ions (see rejection to claim 1 above), It is expected that the

applied power for each frequency will have an effect on their interaction and one of ordinary skill in the art would expect that the ratio of the powers can be used to tune the energy distribution of the ions since Demaray teaches the effect of the frequencies on the ions. The higher frequency controls electron/ion density the lower frequency controls ion bombardment (through the sheath or DC potential) according to Demaray.

As to claim 9, Demaray discloses supplying a third RF signal (18) to a second electrode (under (17)) to form the plasma.

As to claims 11 and 12, it is noted that Demaray is silent about special uniformity profiles for the RF signals. The reference of Georgieva shows that the spatial electric field distribution (electric fields are related to plasma excitation in a plasma) depends on the excitation frequency (figures 2 and 3) while the electric fields remain in the same order of magnitude, it is clear that these figures show different spatial distributions for different frequencies.

Therefore, it would have been obvious to one of ordinary skill in the art at the time the invention was made to expect the first and second RF signals to provide similar excitation with different spatial distribution as taught by Georgieva. Clearly Georgieva shows the varying effect on the power distribution in the plasma from the two RF signals (figure 3), and use superposition to obtain a uniform characteristic of the processing plasma because plasma uniformity is necessary for processing uniformity. One of ordinary skill in the art would have been motivated to use superposition of two complementary energy distributions

in order to obtain a combined uniform energy distribution desirable for uniform processing.

(d) Claim 13, are rejected under 35 U.S.C. 103(a) as being unpatentable over Demaray et al. (US 2003/0127319) in view of Georgieva et al. (Journal of Applied Physics, Vol. 94, No. 6, Sept. 15 2003, pages (3748-3756) as applied to claims 10-12 above, and further in view of Lieberman et al. (Plasma Sources Sci. Technol., vol.11 (2002) (pages 283-293).

it is noted that Demaray is silent about selecting the first and second RF signals to produce a flat power distribution.

The reference of Georgieva teaches spatial distribution is different for different frequency, and the reference of Lieberman teaches radial plasma electric field distribution is different for different frequencies as well (figure 8 and 10). Therefore, it would have been obvious to one of ordinary skill in the art at the time the invention was made to modify the method of Demaray to obtain even higher uniformity by selecting the proper parameters for the plasma and combining complementary first and second frequencies energy distributions to obtain an net radial power distribution that is substantially uniform because the reference of Lieberman teaches how spatial power distribution (page 287) depends on frequency. One of ordinary skill in the art would be motivated modify the method of Demaray to include the teachings of Lieberman in order to obtain a

highly uniform process area which is desirable for plasma processing in general by combining two frequencies with complementing energy or power distributions.

(e) Claim 33 are rejected under 35 U.S.C. 103(a) as being unpatentable over Demaray et al. (US 2003/0127319) as applied to claims 1, in further view of Georgieva et al. (Journal of Applied Physics, Vol. 94, No. 6, Sept. 15 2003, pages (3748-3756) and Lieberman et al. (Plasma Sources Sci. Technol., vol.11 (2002) (pages 283-293).

Demaray discloses 13.56 MHz, 100 to 400 KHz (page 5, paragraph 0043) and 2 MHz (page 11, paragraph 0086) are conventionally used in the art. It is noted that Demaray fails to disclose 13.56 MHz and 2 MHz on the same electrode.

The references of Georgieva (27 MHz and 2 MHz) and Lieberman (13.56 MHz and 40.7 MHz) teach the benefits of dual frequency and these are not limited to mixing 13.56 MHz and 100 to 400 KHz on the same electrode, but frequencies can be mixed across a wider frequency spectrum (page 3748, cols. 1 and 2). Therefore, it would have been obvious to one of ordinary skill in the art at the time the invention was made to modify the method of Demaray to obtain higher uniformity by mixing 13.56 MHz and 2 MHz on the same electrode for applications not requiring high ion bombardment because Demaray teaches the highest ion bombardment is obtained at the lowest frequency and Georgieva along with Lieberman teach frequency mixing has an effect on process

uniformity. One of ordinary skill in the art would have been motivated use the teachings of the three references above to arrive at a proper frequency combination while utilizing commercially and readily available RF power generators. One who is skilled in the art would be motivated to optimize through routine experimentation of frequency mixing using commercially available RF power supplies. See MPEP § 2144.05 (II)(B).

(f) Claim 14 is rejected under 35 U.S.C. 103(a) as being unpatentable over Demaray et al. (US 2003/0127319) in view of Georgieva et al. (Journal of Applied Physics, Vol. 94, No. 6, Sept. 15 2003, pages (3748-3756) as applied to claims 10-12, in further view of Dhindsa et al. (US 2003/0148611)

Demaray is silent about special uniformity profiles for the RF signals. The reference of Dhindsa describes an etch chamber where two RF signals are supplied to a cathode (figure 2) and provide control for plasma uniformity (figure 4) (page 3, paragraph 0035).

Therefore, it would have been obvious to one of ordinary skill in the art at the time the invention was made to use the method of Dhindsa to control the uniformity of a plasma enhanced etched process because Dhindsa discloses such a method to achieve etch rate uniformity across the wafer (Fig.4). As to the details of the plasma theory and models, the limitations of claims 1, 10, 11 and 12 have been discussed above.

(g) Claims 34, 35, 37, 38, 39 are rejected under 35 U.S.C. 103(a) as being unpatentable over Dhindsa et al. (US 2003/0148611) in view of Lieberman et al. (Plasma Sources Sci. Technol., Vol.11 (2002) (pages 283-293).

Dhindsa discloses dual frequency 2 MHz and 27 MHz is conventionally used in plasma semiconductor processing for uniformity in processing (etching), but is silent about energy distributions (paragraph 0029). Demaray discloses dual frequency dual frequency 13.56 MHz and 100-400 KHz for plasma processing (paragraph 0043).

Lieberman teaches energy distribution for different frequencies (13.56 MHz and 40.7 MHz) have different spatial profiles (page 287)

Therefore, it would have been obvious to one of ordinary skill in the art at the time the invention was made to further improve the method of Demaray and Dhindsa by determining the desired energy distribution and selecting the proper conditions in order to form a resulting energy distribution from two frequencies with complementing energy distribution profiles because Lieberman teaches energy distributions are frequency dependant. One of ordinary skill in the art would have been motivated to combine an effect which yields a center-low energy distribution with another effect yielding a center-high energy distribution in order to obtain a resulting substantially flat uniform energy or power distribution.

One who is skilled in the art would be motivated to optimize through routine experimentation of power ratio between the two RF signals. See MPEP § 2144.05 (II)(B).

(h) Claims 36 is rejected under 35 U.S.C. 103(a) as being unpatentable over Dhindsa et al. (US 2003/0148611) in view of Lieberman et al. (Plasma Sources Sci. Technol., Vol.11 (2002) (pages 283-293), as applied to claim 34, and in further view of Demaray et al. (US Pub.No. 2003/0127319) and Georgieva et al. (Journal of Applied Physics, Vol. 94, No. 6, Sept. 15 2003, pages (3748-3756).

Dhindsa discloses providing 2 MHz and 27 MHz simultaneously by a dual frequency source, but Dhindsa is silent about 13.56 MHz.

Demaray discloses 13.56 MHz, 100 to 400 KHz (page 5, paragraph 0043) and 2 MHz frequencies (page 11, paragraph 0086) are conventionally used in the art. It is noted that Demaray fails to disclose 13.56 MHz and 2 MHz on the same electrode.

The references of Georgieva (27 MHz and 2 MHz) and Lieberman (13.56 MHz and 40.7 MHz) teach energy distribution variation from one frequency to another are not limited to any combination of frequency such as 13.56 MHz and 100 to 400 KHz.

Therefore, it would have been obvious to one of ordinary skill in the art at the time the invention was made to modify the method of Dhindsa to obtain higher uniformity by mixing 13.56 MHz and 2 MHz on the same electrode for applications not requiring high ion bombardment because Demaray teaches the highest ion bombardment is obtained at the lowest frequency and Georgieva along with Lieberman teach different frequencies have different energy distributions. One of ordinary skill in the art would have been motivated use the

teachings of the three references above to arrive at a proper frequency combination while utilizing commercially and readily available RF power generators. One who is skilled in the art would be motivated to optimize through routine experimentation of frequency mixing using commercially available RF power supplies. See MPEP § 2144.05 (II)(B).

(i) Claims 43-46 are rejected under 35 U.S.C. 103(a) as being unpatentable over Dhindsa et al. (US 2003/0148611) in view of Lieberman et al. (Plasma Sources Sci. Technol., Vol.11 (2002) (pages 283-293).

Dhindsa discloses the electrode (202) beneath a substrate (204) support surface in the etch chamber (200) (paragraphs 0023 and 0024, Fig.2), wherein the electrode is a cathode (208) (paragraph 0024), etching a substrate disposed on the substrate support (paragraph 0024), wherein the electrode is disposed beneath a substrate support in the etch chamber (fig.2) (paragraph 0024).

(10) Response to Arguments

(a) *With respect claims 1, 14 and 34-39,* Appellant's arguments asserting that the reference of Demaray does not disclose or suggest any interaction between the first and second RF signals applied to the target are not convincing. Demaray discloses that the plasma process chamber uses dual frequency one at higher frequency (13.56 MHz) and the other at lower frequency from 100-400 kHz, and for any given deposition, the low frequency power is from about a tenth

to about three quarters of the high frequency power. The high frequency accelerates electrons in the plasma, which is not efficient at accelerating the much slower heavy ions in the plasma. Adding a low frequency, according to Demaray causes ions in the plasma to bombard the film being deposited on the substrate, resulting in sputtering and densification of the film. In the plasma chamber the first and second frequency RF power signals are involved in a dynamic process to optimize the characteristics of the plasma and hence the deposition or etch conditions (paragraph 0043). Demaray discloses the benefits of using dual frequencies in the form of increased refractive index of the deposited film (paragraph 0045). In plasma etching, first and second frequencies are varied and the ratio of these frequencies is a result variable which can be optimized to control plasma etching.

(b) *With respect to claim 2,* Demaray discloses that the plasma characteristics controlled by the interaction of the first and second RF signals results in sheath modulation (paragraph 0047). The sheath formation in the chamber is due to application of bias to the substrate, which is akin to the effect of adding the low frequency RF power to the high frequency power to the source.

(c) *With reference to claim 10,* Demaray discloses that using the first and second frequency RF power in the plasma and modulating the flow of charge carriers would control the power distribution within the plasma (paragraph 0043). Demaray teaches that the dual frequency interaction in an RF deposition process

causes reduced surface roughness (paragraph 0044) and further highlighted in Example 4 (paragraphs 0082 and 0083).

(d) *With reference to claims 4-9, 11 and 12,* Appellant's arguments asserting that the combined reference of Demaray and Georgieva do not reveal all the limitation of claims are again not persuasive. In fact, Georgieva presents extensive simulation results of the potential and electric-field distribution in the single and dual-frequency regime (Figs. 2 and 3, page 3751). The maximum and minimum values of the potential at the driven electrode in the dual-frequency regime are almost twice as large as those in the one-frequency regime for the same applied voltage amplitude.

(e) *With reference to claims 13 and 33,* Appellant's arguments asserting that the combined reference of Demaray in view of Georgieva and Lieberman are not persuasive. Georgieva discloses that the interaction between first and second RF signals is used to control the characteristics of plasma and the film formed in the chamber (paragraphs 0043, 0045). Lieberman teaches radial plasma electric field distribution for different frequencies (see Figs. 8 and 10).

(f) *With reference to claims 34-35 and 37-39,* Appellant's arguments are not persuasive. The combined reference of Dhindsa and Lieberman meets the limitations of these claims. Lieberman teaches energy distribution for different frequencies (13.56 MHz and 40.7 MHz) have different spatial profiles (page 287).

Therefore, it would have been obvious to one of ordinary skill in the art at the time the invention was made to further improve the method of Demaray and

Dhindsa by determining the desired energy distribution and selecting the proper conditions in order to form a resulting energy distribution from two frequencies with complementing energy distribution profiles because Lieberman teaches energy distributions are frequency dependant.

(g) *With reference to claim 36,* Appellant's arguments are not persuasive. One who is skilled in the art should be able to choose any combination of frequencies in the range from about 2 to 40.7 MHz as illustrated by Demaray, Dindsa and Lieberman and discussed above.

(h) *With respect to claims 43-46,* Appellants arguments are not persuasive since the reference of Dhindsa illustrates the position of electrostatic chuck and electrodes in a plasma processing chamber that is typically employed to etch a substrate (paragraphs 0023-0026, Fig.2) using dual RF frequencies e.g. 2MHz and 27 MHz (paragraph 0023). One who is skilled in the art should be able to employ other combination of dual frequencies for plasma etching.

(11) Related Proceeding(s) Appendix

No decision rendered by a court or the Board is identified by the examiner in the Related Appeals and Interferences section of this examiner's answer.

For the above reasons, it is believed that the rejections should be sustained.

Respectfully submitted,

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